Survey of Red Sea Urchin Populations in the Deserters Group area, Queen Charlotte Strait, British Columbia, 2000

D. Tzotzos, A. Campbell, and D. Bureau

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

2003

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2628

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques ques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits a l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques ques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits a l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

103-04639/

Canadian Manuscript Report of

Fisheries and Aquatic Sciences 2628

2003

SURVEY OF RED SEA URCHIN POPULATIONS IN THE DESERTERS GROUP AREA, QUEEN CHARLOTTE STRAIT, BRITISH COLUMBIA, 2000

by

D. Tzotzos[1], A. Campbell, and D. Bureau

Fisheries and Oceans Canada

Science Branch, Pacific Region

Pacific Biological Station

Nanaimo, British Columbia

V9T 6N7

[1]Pacific Urchin Harvesters Association
902 – 4th Street,
New Westminster, British Columbia
V3L 2W6

© Her Majesty the Queen in Right of Canada, 2003,
as represented by the Minister of Fisheries and Oceans.
Cat. No. Fs 97-4/2628E ISSN 0706-6473

Correct citation for this publication:

Tzotzos, D., A. Campbell, and D. Bureau. 2003. Survey of red sea urchin populations in the Deserters Group area, Queen Charlotte Strait, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2628: 16 p.

ABSTRACT

Tzotzos, D., A. Campbell, and D. Bureau. 2003. Survey of red sea urchin populations in the Deserters Group area, Queen Charlotte Strait, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2628: 16 p.

A survey of red sea urchin populations from the Deserters Group area in Queen Charlotte Strait, parts of Pacific Fishery Management (PFM) Area 12, was conducted in November 2000. A total of 57 randomly placed transects were surveyed by SCUBA divers. Estimated mean density was 2.12 urchins per m^2. Estimated mean biomass was 812.4 g per m^2. Overall, 3.6% of the total number of urchins measured were ≤50 mm test diameter (TD), whereas 73.0% were of legal size (≥ 90 mm TD) for the commercial fishery.

RÉSUMÉ

Tzotzos, D., A. Campbell, and D. Bureau. 2003. Survey of red sea urchin populations in the Deserters Group area, Queen Charlotte Strait, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2628: 16 p.

Un relevé des populations d'oursins rouges des îles Deserters, situées dans le détroit de la Reine-Charlotte, qui fait partie du secteur d'exploitation des pêcheries du Pacifique 12, a été réalisé en novembre 2000. Des plongeurs autonomes ont effectué ce relevé sur 57 transects placés aléatoirement. La densité moyenne estimée s'élevait à 2,12 oursins par m^2. La biomasse moyenne était estimée à 812,4 g/m^2. Dans l'ensemble, le diamètre du test de 3,6 % du nombre total d'oursins mesurés était ≤ 50 mm, alors que 73,0 % des oursins étaient de taille légale (diamètre du test ≥ 90 mm) pour la pêche commerciale.

INTRODUCTION

Red sea urchin (*Strongylocentrotus franciscanus*) distribution along the Pacific Coast of North America ranges from the southern tip of Baja California to Alaska (Kato and Schroeter 1985). The red sea urchin is found throughout shallow rocky subtidal habitats of British Columbia (Bernard 1977; Campbell and Harbo 1991). Red sea urchins are commercially harvested for their gonads (roe), which are sold mainly in Japan. Coastal First Nations communities harvest sea urchins as part of their food, social, and ceremonial fisheries. The commercial red sea urchin fishery started in British Columbia (BC) in the early 1970's and the total landed value for the 2000-2001 season was $8.4 million (Campbell et al. 2001), making the red sea urchin fishery one of the most valuable shellfish fisheries in BC.

The commercial red sea urchin fishery history and management are described in Campbell and Harbo (1991), and Campbell et al. (1999a). Currently, several approaches are used in the management of the red sea urchin fishery, including: a minimum commercial harvest size of 90 mm test diameter (TD); area licensing; individual vessel quotas; area quotas; and limited licence entry. Quota calculations are based on estimates of urchin density from field surveys, and estimates of urchin bed areas. Density estimates are therefore essential to the assessment and management of the red sea urchin fishery.

Early red sea urchin population surveys were conducted during the 1970's and 1980's by Adkins et al. (1981), Breen et al. (1976, 1978) and Sloan et al. (1987). Since 1993, red sea urchin population surveys have been conducted as a joint effort between the Pacific Urchin Harvesters Association (PUHA), First Nations, and Fisheries and Oceans Canada (DFO) (Jamieson et al. 1998a, 1998b, 1998c, 1998d; Bureau et al. 2000a, 2000b, 2000c, 2000d; Tzotzos et al. 2003a (in press), 2003b (in press)).

Fishery managers requested that red sea urchin surveys be conducted to update density and biomass estimates to help determine quotas. The Deserters Group area [parts of Pacific Fishery Management (PFM) Area 12, sub-area 13], near Gordon Channel, Queen Charlotte Strait (Figure 1), was selected for survey through discussion between DFO and PUHA. The objective of this paper was to present detailed survey results and to estimate current red sea urchin biomass for PFM sub-area 12-13. The biomass estimate was converted into quota recommendations for the PFM sub-area, for management purposes by Campbell et al. (2001).

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Survey efforts were concentrated in the Deserters Group area of Queen Charlotte Strait. The entire survey was completed in PFM sub-area 12-13. Transect locations were selected and plotted on a marine chart prior to the survey to avoid biases in the field. The number of transects assigned to each section was proportional to the surface area of water between 0 and

10 m below chart datum of each section over the total surface area of water between 0 and 10 m in the survey area. All depths have been corrected to chart datum.

Transect layout along the shoreline was done by systematically placing transects along shore with a random starting point. Areas of sandy substrate were excluded from the survey area. Total shoreline length (TSL) of the survey area was measured using a digital curvimeter and marine charts. Position of the first transect was determined randomly, subsequent transects were then spaced evenly along the shoreline. Distance between transects was TSL/n where n is the number of transects along the shoreline. Since fluctuations in urchin density are unlikely to match the spacing of the transects, the systematic sample may therefore be treated as a random sample of transects (Jamieson and Schwarz 1998). Transects around islets were plotted by randomly choosing islets and then assigning a random compass bearing to determine the position and direction for each of the transects off an islet.

SURVEY LOGISTICS

The survey was conducted between November 13 and November 18, 2000, on the "Cucumber Cowboys", a commercial red sea urchin fishing vessel. A crew of five people, consisting of four divers and a boat tender, was used for the survey. The vessel docked at Port Hardy each night, and travelled to the survey area each day.

DIVE SURVEY METHODS

Leadline transects were laid perpendicular to shore from the boat. Transects were laid out from shallow water to a depth of 15 m, so transect length was dependent on the slope of the substrate. A float was attached to the deep end of each transect. A two-diver team surveyed each transect from deep to shallow, one diver measured urchins while the other recorded data. A one meter squared (1 m^2) quadrat was placed on the bottom beside the transect and the test diameter (TD) of each red urchin present was measured to the nearest millimeter with calipers. The depth, substrate type, types of algae (and percent cover), and numbers of abalone (*Haliotis kamtschatkana*), green (*Strongylocentrotus droebachiensis*) and purple (*Strongylocentrotus purpuratus*) sea urchins present in the quadrat were also recorded. The quadrat was then moved 2 m forward along the transect and the process was repeated, so that every second meter of the transect was surveyed. In cases where the substrate was sand and no urchins were found at the deep end of transects, observations of depth, substrate and algae were recorded only every 20 m to minimize dive time. In such cases, skipped quadrats were assigned zero values for urchin counts before data were analysed. Once urchins were encountered, sampling was conducted every 2 m until the intertidal zone or the surface was reached. On long transects with large numbers of urchins, measurements of test diameters were recorded in only a portion of the quadrats surveyed (usually half). The number of urchins measured on a transect could therefore be smaller than the number of urchins counted.

ESTIMATION OF DENSITY AND BIOMASS

Density and biomass estimates were calculated from the randomly placed transects which were located in red sea urchin beds recorded from 1997 to 2000. For comparison, estimates were also calculated for transects located outside of the recorded red sea urchin beds, and for all transects combined. The process involved in defining the commercially harvested urchin beds is described by Campbell et al. (2001).

Density and biomass were estimated for urchins of two size groups: a) all sizes; and, b) for urchins of legal size for the commercial fishery (≥90 mm TD). Estimates of mean density and biomass were calculated using the equations below.

Density estimates (d_{ts}) in numbers per meter squared for each transect (t) and size group (s) were calculated as:

$$d_{ts} = \frac{N_{ct}}{a_t} * \frac{N_{mts}}{N_{mt}}$$

where N_{ct} is the total number of urchins counted on transect t, N_{mts} is the number of urchins measured in size group s on transect t, N_{mt} is the total number of urchins measured on transect t, and a_t is the surface area of all quadrats surveyed on the transect t. Here a_t is equal to the number of all quadrats surveyed on the transect since each quadrat had a surface area of 1 m^2.

Overall mean density ($\bar{d}_s$) for a PFM sub-area for urchins of size group s was estimated as:

$$\bar{d}_s = \frac{\sum_t (d_{ts} * L_t)}{\sum_t L_t}$$

where L_t is the length of transect t (Campbell et al. 1999b).

The standard error ($s_{\bar{d}}$) of estimated mean density was calculated as:

$$s_{\bar{d}} = \sqrt{1 - \frac{n}{T}} * \sqrt{\frac{\sum_t (d_{ts} * L_t - \bar{d}_s * L_t)^2}{n * (n-1) * \bar{L}^2}}$$

where n is the number of transects surveyed, T is the total possible number of transects that can be sampled in a surveyed PFM sub-area and mean transect length ($\bar{L}$) was calculated as:

$$\bar{L} = \frac{\sum_t L_t}{n}$$ (Campbell et al. 1999b)

The expression $\sqrt{(1-(n/T))}$ was approximately equal to 1 since n was much smaller than T.

To calculate biomass, the weight of each urchin measured was calculated using the relationship between urchin weight (*W*) in grams and test diameter (*TD*) in millimetres (Campbell et al. 1999b, 2000).

$$W = 0.0012659 * TD^{2.7068} \quad n= 167, r^2=0.960$$

Biomass density (b_{ts} in grams per meter squared) of urchins of size group *s*, on a transect *t*, was estimated using a simplified form of the formula used in previous papers (Campbell et al. 2000). The formula was modified by Campbell et al. (1999b) to simplify computations:

$$b_{ts} = \frac{N_{ct}}{N_{mt}} * \frac{\sum W_{ts}}{a_t}$$

where ΣW_{ts} is the sum of the weights of urchins measured in size group *s* on transect *t* and a_t is the surface area of quadrats surveyed on the transect *t*.

Overall estimated mean biomass ($\overline{b_s}$) per surface area (grams per meter squared) was calculated as:

$$\overline{b_s} = \frac{\sum_t (b_{ts} * L_t)}{\sum_t L_t} \qquad \text{(Campbell et al. 1999b)}$$

The standard error of estimated mean biomass was calculated using the same formula used for standard errors of density, but d_{ts} and $\overline{d}_s$ were substituted for b_{ts} and $\overline{b}_s$, respectively.

Estimates of recruitment (R_T) into red sea urchin populations in BC have generally been expressed as the percent of the total number of red sea urchins measured that were ≤50 mm TD (Adkins et al. 1981; Breen et al. 1976, 1978; Jamieson et al. 1998b, 1998c, 1998d; Sloan et al. 1987). We used the same method for comparison purposes. We also calculated recruitment as the percent of the total number of sublegal red sea urchins (<90 mm TD) that were ≤50 mm TD (R_S). This method may provide a less biased measure of recruitment in areas where a commercial fishery has taken place, since the numbers of sea urchins ≥90 mm TD would be reduced due to the harvest (Tegner and Dayton 1981).

The data from Jamieson et al. (1998b, 1998c, 1998d) used for comparison to the current survey has undergone some reanalysis resulting in some quoted values being slightly different from those in the original papers.

RESULTS

SURVEY LOGISTICS

A total of 57 transects were surveyed in seven days (Table 1, Figure 1). A total of 3116 red sea urchins were counted, and test diameters of 2238 red sea urchins were measured in 978 quadrats on the 57 transects. Total transect length surveyed was 1899 m, for an average transect length of 33 m. Nine transects were located in the commercial red sea urchin beds recorded from 1997 to 2000.

All transects surveyed were in PFM sub-area 12-13. The transects were spread over most of the islands in the sub-area, but did not include that section of the mainland shoreline that falls within PFM sub-area 12-13. The density and biomass estimates obtained may therefore not be representative of the whole of PFM sub-area 12-13.

SUBSTRATE AND HABITAT

Generally, the survey area was characterised by steep slopes, accounting for the relatively short transects. Bedrock (smooth and creviced) was the primary substrate in 807 (82.5%) quadrats. Shell, sand, and mud were the primary substrate types in 108 (11.0%) quadrats.

Out of a total 3116 red sea urchins counted, 57.1% were observed between 0.0 m and 4.9 m. One hundred percent of the quadrats between 0.0 m and 4.9 m had bedrock as their primary substrate type. Of all red sea urchins counted, 90.9% were observed on transects with an exposure value of ≥4 (moderate exposure). Forty-nine of the 57 transects had exposure values of ≥4 (Table 2).

The highest mean numbers of red sea urchins were observed in 0.0 m - 4.9 m depth (categories 2 and 3 in Table 2). These depth categories also had the highest mean percent canopy and encrusting algae cover (Table 2).

SIZE FREQUENCY DISTRIBUTIONS

The overall mean size of red sea urchins measured was 102.4 mm TD (Table 3). The smallest and largest urchins measured were 6mm and 165 mm TD, respectively. The overall percent of legal sized urchins (≥90 mm TD) was 73.0%, whereas the overall percent of urchins ≤50 mm TD (R_T) was 3.6%. Of the sublegal urchins, the portion that were ≤50 mm TD (R_S) was 13.4%.

DENSITY AND BIOMASS ESTIMATES

For transects that fell within recorded red sea urchin beds, the estimated mean density of urchins of all sizes was 2.12 urchins per m^2, and 1.52 urchins per m^2 for legal sized urchins (Table 4). The estimated mean biomass of red sea urchins of all sizes was 812.4 g per m^2, and

726.4 g per m^2 for legal sized urchins (Table 4). Transects which fell outside the recorded red sea urchin beds had higher estimated mean density and biomass values than the transects within the recorded bed areas (Table 4).

DISCUSSION

Red sea urchin populations often have low recruitment (Bernard 1977; Sloan *et al.* 1987), an observation that is supported by this survey. The size frequency distribution of red sea urchins from the current survey indicated a relatively low recruitment of R_T=3.6%, R_S=13.4% (Table 3; Figure 2), which is lower than the R_T=9.1% recruitment reported by Jamieson (1998d) for PFM Area 12 in 1994. A survey conducted in the Robson Bight region of Johnstone Strait in 2001 had recruitment levels of R_T=20.0% and R_S=46.8% (unpublished data), considerably higher than the levels observed during the current survey.

High variability in recruitment levels within an area may be caused by many factors including predation on larvae and juveniles, interactions between juveniles and conspecific adults, and physical and oceanographic characteristics of the region (Kalvass 1992; Sloan et al. 1987). The Deserters Group and neighbouring islands are situated in a location with high water movement. High current may play a major role in keeping local recruitment levels low.

The percentage of legal sized urchins (≥90 mm TD) in the present survey was 73.0% (Table 3), which is close to the 68.6% observed by Jamieson (1998d) for PFM Area 12 in 1994. The other surveys conducted in 2000 showed percentages of legal sized red urchins of 42.3% in Laredo Channel, and 46.7% in Tofino (Tzotzos et al. 2003b (in press), 2003a (in press)).

The density estimate of 2.12 urchins per m^2 from the current survey fell between the values observed during other surveys conducted in 2000. The Laredo Channel and Tofino surveys conducted in 2000 showed red sea urchin densities of 1.33 urchins per m^2 and 2.39 urchins per m^2, respectively (Tzotzos et al. 2003b (in press), 2003a (in press)). The biomass estimate of 812.4 g/m^2 from the current survey was higher than both the Laredo Channel (325.9 g/m^2), and the Tofino (621.9 g/m^2) estimates (Tzotzos et al. 2003b (in press), 2003a (in press)). The mean overall density for the survey conducted in Queen Charlotte Strait and Broughton Strait in 1994 was 1.11 urchins per m^2 (Jamieson et al. 1998d), lower than the estimated mean of 3.18 urchins per m^2 (for all transects) observed during the current survey.

The differences in density and biomass estimates between the transects within the recorded red sea urchin beds and those that fell outside the beds may have a number of explanations. One possibility is that the harvest of red urchins has caused a decrease in abundance in the harvested locations. In such a case, an associated drop in mean test diameter and percent of legal sized urchins would be expected, due to the removal of urchins ≥90 mm TD. The current survey shows no evidence of this (Table 3). Another possibility is that the commercial harvest has been concentrated in areas of lower urchin density due to roe quality concerns. In areas of high urchin density, roe quality could be diminished due to the reduced availability of food to each urchin.

For the most part, the recorded red sea urchin beds in the survey area lie along the southern shores of the islands. The fishing activity is influenced by a number of factors, including the area quota, number of vessels fishing, weather, and the distance from landing port. With 5-6 vessels fishing, the divers do not need to cover a very large area to fill the quota, so they tend to go back to the same locations each year since they know where to find urchins with good quality roe (Ken Ridgway, PUHA, pers. comm.). The prevailing weather at the time of year that fishing generally takes place in the Deserters Group is such that the southern shore is the most protected, making diving easier and safer (Ken Ridgway, PUHA, pers. comm.).

ACKNOWLEDGEMENTS

We thank Edith Kraus, Doug Brouwer, Fraser Stothart, and Martin Lelewiski for conducting the dive survey, Richard Strong for boat tending, the PUHA for providing financial and logistical support for the survey, Wayne Hajas for statistical analysis support, and Brenda Waddell for reviewing this paper.

REFERENCES

Adkins, B. E., R. M. Harbo, and P. A. Breen. 1981. A survey of commercial sea urchin (*Strongylocentrotus franciscanus*) populations in the Gulf Islands, November 1980. Can. Manuscr. Rep. Fish. Aquat. Sci. 1618: 41 p.

Bernard, F. R. 1977. Fishery and reproductive cycle of the red sea urchin, *Strongylocentrotus franciscanus*, in British Columbia. J. Fish. Res. Board Can. 34: 604-610.

Breen, P. A., B. E. Adkins, and D. C. Miller. 1978. Recovery rate in three exploited red sea urchin populations from 1972 to 1977. Fish. Mar. Serv. Manuscr. Rep. 1446: 27 p.

Breen, P. A., D. C. Miller, and B. E. Adkins. 1976. An examination of harvested sea urchin populations in the Tofino area. Fish. Res. Board Can. Manuscr. Rep. 1401: 23 p.

Bureau, D., A. Campbell, and W. C. Hajas. 2000a. Survey of red sea urchin populations near Comox, Denman Island and Hornby Island, British Columbia, 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2546: 17 p.

Bureau, D., A. Campbell, and W. C. Hajas. 2000b. Survey of red sea urchin populations in the Kelsey Bay Area, Johnstone Strait, British Columbia, 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2542: 19 p.

Bureau, D., A. Campbell, W. C. Hajas, and C. A. Ayers. 2000c. Survey of red sea urchin populations in the Gulf Islands, Strait of Georgia, British Columbia, 1998 and 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2552: 29 p.

Bureau, D., A. Campbell, and W. C. Hajas. 2000d. Survey of red sea urchin populations in the Larsen Harbour and Kingkown Inlet areas, Banks Island, British Columbia, 1997. Can. Manuscr. Rep. Fish. Aquat. Sci. 2551: 19 p.

Campbell, A. and R. M. Harbo. 1991. The sea urchin fisheries in British Columbia, Canada, p.191-199. *In:* T. Yanagisawa, I. Yasumasu, C. Oguro, N. Suzuki, T. Motokawa, [eds.]. Biology of echinodermata. A. A. Balkema, Rotterdam.

Campbell, A., J. Boutillier, and J. Rogers. 1999a. Discussion on a precautionary approach for management of the red sea urchin fishery in British Columbia. Can. Stock Assessment Secretariat Res. Doc. 99/094: 49 p.

Campbell, A., W. Hajas, and D. Bureau. 1999b. Quota options for the red sea urchin fishery in British Columbia for fishing season 2000/2001. Can. Stock Assessment Secretariat Res. Doc. 99/201: 67 p.

Campbell, A., D. Bureau, and D. Brouwer. 2000. Quota estimates for the 1998 red sea urchin fishery in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2516: 31 p.

Campbell, A., D. Tzotzos, W.C. Hajas, and L.L. Barton. 2001. Quota options for the red sea urchin fishery in British Columbia for fishing season 2002/2003. Can. Stock Assessment Secretariat Res. Doc. 2001/141.

Jamieson, G. S. and C. J. Schwarz. 1998. Survey protocol considerations for 1995 red sea urchin surveys, p.69-81. *In*: B. J. Waddell, G. E. Gillespie, and L. C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Jamieson, G. S., K. Cripps, M. Gijssen, L. Greba, R. Jones, G. Martel, W. Sandoval, C. J. Schwarz, C. Taylor, and R. Routledge. 1998a. Reanalyses of the 1993 red sea urchin surveys conducted in Haida, Heiltsuk, Kitasoo and Tsimshian traditional territories, p.57-68. *In*: B. J. Waddell, G. E. Gillespie, and L. C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Jamieson, G. S., R. Jones, G. Martel, C. J. Schwarz, C. Taylor, and R. Routledge. 1998b. Analysis of the 1994 red sea urchin survey conducted in Haida Gwaii, Pacific Fishery Management Area 1, p.3-18. *In*: B. J. Waddell, G. E. Gillespie, and L. C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Jamieson, G. S., W. Sandoval, C. J. Schwarz, C. Taylor, and R. Routledge. 1998c. Analysis of the 1994 red sea urchin surveys conducted in Heiltsuk traditional territory, Pacific Fishery Management Area 7, subareas 18 and 25, p.19-31. *In*: B. J. Waddell, G. E. Gillespie, and L. C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Jamieson, G. S., G. Scarf, C. J. Schwarz, C. Taylor, and R. Routledge. 1998d. Analysis of the 1994 red sea urchin surveys conducted in Aweena K'ola traditional territory, subareas of Pacific Fishery Management Area 12, p.33-56. *In*: B. J. Waddell, G. E. Gillespie, and L. C. Walthers [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part 2. Echinoderms. Can. Tech. Rep. Fish. Aquat. Sci. 2215.

Kalvass P. 1992. The Northern California commercial sea urchin fishery – a case study. *In*: The management and enhancement of sea urchins and other kelp bed resources: a Pacific Rim perspective. California Sea Grant College, Report No. T-CSGCP-028.

Kato S. and S. C. Schroeter. 1985. Biology of the red sea urchin, *Strongylocentrotus franciscanus*, and its fishery in California. Mar. Fish. Rev. 47(3): 1-20.

Sloan N. A., C. P. Lauridsen, and R. M. Harbo. 1987. Recruitment characteristics of the commercially harvested red sea urchin *Strongylocentrotus franciscanus* in southern British Columbia, Canada. Fish. Res. 5: 55-69.

Tegner, M. J. and P. K. Dayton. 1981. Population structure, recruitment and mortality of two sea urchins (*Strongylocentrotus franciscanus* and *S. purpuratus*) in a kelp forest. Mar. Ecol. Prog. Ser. 5: 255-268.

Tzotzos D., A. Campbell, and D. Bureau. 2003a. Survey of red sea urchin populations in the Tofino area, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2630: 18 p.

Tzotzos D., A. Campbell, and T. Norgard. 2003b. Survey of red sea urchin populations in Laredo Channel, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2629: 20 p.

Table 1. Summary of transects surveyed during the 13-18 November, 2000 red sea urchin (RSU) population survey in the Deserters Group area of Queen Charlotte Strait. Density in number per meter squared and biomass in grams per meter squared. PFM = Pacific Fishery Management. Depths have been corrected to chart datum. Check marks (✓) indicate transect lying within a known commercial RSU bed.

Transect	PFM Sub-Area	Latitude	Longitude	Depth (m) Minimum	Depth (m) Maximum	Time Start	Time End	Total Time (minutes)	Transect Length	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
2	12-13	50 54.681	127 35.836	3.38	11.61	11:55	12:05	10	19	10	58	5.80	1487.61	
3	12-13	50 54.462	127 35.754	0.30	12.22	12:10	12:35	25	43	22	127	5.77	1202.42	
4	12-13	50 54.41	127 35.413	1.19	18.59	12:40	12:50	10	33	17	79	4.65	649.53	
5	12-13	50 54.343	127 35.204	0.52	11.55	13:00	13:12	12	17	9	75	8.33	2162.45	
6	12-13	50 53.877	127 34.696	-0.52	11.46	13:20	13:40	20	55	28	99	3.54	1126.81	
7	12-13	50 53.25	127 33.476	-1.31	7.68	9:18	9:36	18	41	21	107	5.10	1236.03	
8	12-13	50 55.094	127 34.716	3.96	11.25	11:35	11:45	10	21	11	103	9.36	1368.90	
9	12-13	50 54.65	127 34.709	-0.40	11.09	10:50	11:18	28	51	26	164	6.31	710.33	
11	12-13	50 54.691	127 34.159			10:22	10:40	18	33	17	95	5.59	737.41	
12	12-13	50 54.106	127 33.562	1.10	10.70	9:51	10:12	21	35	18	98	5.44	1351.90	
13	12-13	50 55.47	127 30.083	-0.94	10.45	13:34	13:50	16	19	10	60	6.00	1570.19	
14	12-13	50 55.288	127 32.541	-0.46	10.94	13:14	13:29	15	27	14	95	6.79	841.86	
15	12-13	50 55.044	127 32.243	0.37	10.94	12:36	13:08	32	67	34	121	3.56	340.58	
16	12-13	50 55.039	127 32.077	0.00	10.45	12:13	12:30	17	25	13	97	7.46	1080.98	
17	12-13	50 54.857	127 32.5	-1.07	11.19	11:56	12:04	8	25	13	14	1.08	482.21	
18	12-13	50 54.521	127 31.805	-0.37	10.97	11:33	11:44	11	25	13	21	1.62	592.38	
19	12-13	50 54.356	127 31.383	-1.22	11.00	11:16	11:27	11	31	16	38	2.38	982.77	
20	12-13	50 54.021	127 31.458	-1.77	12.86	10:47	11:05	18	49	25	45	1.80	626.66	
21	12-13	50 53.938	127 30.689	0.06	11.61	10:28	10:40	12	19	10	47	4.70	1109.44	

Continued next page

Table 1. continued

Transect	PFM Sub-Area	Latitude	Longitude	Depth (m) Minimum	Depth (m) Maximum	Time Start	Time End	Total Time (minutes)	Transect Length	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
22	12-13	50 53.184	127 30.6	-2.01	10.36	13:03	13:19	16	31	16	45	2.81	1301.81	
23	12-13	50 52.703	127 31.182	-2.50	10.39	13:27	13:37	10	27	14	20	1.43	500.00	
24	12-13	50 52.92	127 31.324	-2.38	9.94	13:42	13:55	13	23	12	85	7.08	1204.39	✓
25	12-13	50 53.127	127 31.786	-3.14	9.14	14:02	14:16	14	27	14	26	1.86	1237.80	
27	12-13	50 54.082	127 32.465	-1.62	10.42	14:14	14:30	16	17	9	47	5.22	2156.92	
28	12-13	50 54.842	127 33.039	-1.13	10.55	14:00	14:09	9	17	9	34	3.78	1330.10	
30	12-13	50 52.805	127 30.135	-1.77	10.39	12:38	12:55	17	39	20	63	3.15	640.58	
31	12-13	50 52.71	127 30.126	-1.22	10.49	12:21	12:31	10	27	14	18	1.29	698.53	
32	12-13	50 52.693	127 29.358	-4.05	9.51	11:34	11:45	11	27	14	29	2.07	764.02	
33	12-13	50 52.616	127 24.271	-4.30	8.96	11:53	12:08	15	31	16	6	0.38	264.74	
34	12-13	50 52.444	127 29.322	-2.26	5.18	13:32	13:44	12	47	24	22	0.92	330.09	✓
35	12-13	50 52.282	127 29.645	-0.09	10.79	11:51	12:14	23	47	24	91	3.79	902.51	
36	12-13	50 52.242	127 29.334	-1.77	11.25	10:53	11:23	30	67	34	79	2.32	726.86	✓
37	12-13	50 52.206	127 29.227	-1.83	11.37	10:35	10:48	13	21	11	22	2.00	594.02	✓
38	12-13	50 52.05	127 27.09	-1.07	10.61	9:11	9:22	11	39	20	10	0.50	188.30	✓
39	12-13	50 52.43	127 28.407	-1.22	9.54	8:51	9:06	15	37	19	10	0.53	443.92	
40	12-13	50 52.05	127 27.09	0.21	11.28	9:35	9:48	13	43	22	19	0.86	303.74	✓
41	12-13	50 52.177	127 27.099	-1.28	9.54	9:57	10:39	42	85	43	69	1.60	628.55	✓
42	12-13	50 52.168	127 26.014	-0.03	9.42	10:49	11:18	29	39	20	70	3.50	2024.05	✓
43	12-13	50 52.413	127 27.186	-0.43	9.85	11:28	12:08	40	59	30	129	4.30	1991.59	
44	12-13	50 52.537	127 27.847	-1.62	9.20	12:18	12:31	13	17	9	34	3.78	1980.78	

Continued next page

Table 1. continued

Transect	PFM Sub-Area	Latitude	Longitude	Depth (m) Minimum	Depth (m) Maximum	Time Start	Time End	Total Time (minutes)	Transect Length	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
45	12-13	50 53.096	127 27.186	-3.66	8.93	12:43	12:54	11	19	10	19	1.90	921.06	
46	12-13	50 53.196	127 28.266	-3.26	6.34	13:00	13:25	25	49	25	101	4.04	1029.53	
47	12-13	50 53.296	127 28.314	-3.32	8.60	13:30	13:42	12	25	13	40	3.08	1108.99	
48	12-13	50 53.564	127 28.567	-3.17	9.14	13:22	13:35	13	15	8	11	1.38	608.30	
49	12-13	50 53.694	127 29.052	0.67	8.99	13:40	13:54	14	13	7	40	5.71	2486.66	
50	12-13	50 53.786	127 29.322	-0.58	10.97	10:05	10:18	13	31	16	62	3.88	1098.17	
51	12-13	50 53.415	127 29.213			10:18	10:33	15	49	25	39	1.56	976.36	
52	12-13	50 53.15	127 29.458	-3.26	7.56	9:55	10:05	10	39	20	0	0.00	0.00	
53	12-13	50 53.208	127 28.781	0.61	8.66	10:45	10:55	10	31	16	32	2.00	630.85	
54	12-13	50 53.801	127 28.8	1.89	9.08	12:31	13:14	43	61	31	124	4.00	618.77	
55	12-13	50 52.56	127 26.465	0.46	11.49	9:45	9:56	11	21	11	24	2.18	684.76	
57	12-13	50 52.494	127 26.123	0.00	11.37	10:04	10:14	10	17	9	40	4.44	1780.80	✓
59	12-13	50 53.177	127 25.712	0.98	12.41	10:25	10:39	14	17	9	6	0.67	490.09	
62	12-13	50 54.327	127 25.883	-0.52	10.61	10:50	11:04	14	47	24	38	1.58	628.94	
63	12-13	50 54.433	127 25.654	-0.43	11.28	11:12	11:22	10	23	12	31	2.58	1698.03	
65	12-13	50 55.054	127 26.618	-0.91	10.45	11:31	11:37	6	15	8	0	0.00	0.00	
66	12-13	50 55.136	127 27.355	2.29	10.09	11:58	12:14	16	25	13	38	2.92	1229.29	

Table 2. Mean percent cover by algae, substrate type, exposure, and number of red sea urchins for each depth category surveyed during the 2000 survey conducted in the Deserters Group area of Queen Charlotte Strait. Depth category ranges (corrected to chart datum): 1 = <0.0m; 2 = 0.0 to <2.5m; 3 = 2.5 to <5.0m; 4 = 5.0 to <7.5m; 5 = 7.5 to <10.0m; 6 = 10.0 to <12.5m; 7 = ≥12.5m. Exposure values: 1=minimal sea movement; 2=well sheltered; 3=occasional current; 4=moderate exposure; 5=strong tidal flow; 6=high tide surge only; 7=ground swell normal; 8=high exposure. Substrate values: 1=rock; 2=sand; 3=mud. Canopy = tall, shading, surface-reaching algae. Understorey = 30cm to 2m in height. Turf = 5cm to 30cm in height. Encrusting = species forming a thin, crusty layer on rocks.

Depth Category	Median Depth (m)	Mean Number of RSU per Quadrat	Number of Quadrats	Mean Substrate Category	Mean Exposure	Mean Percent Cover by Algae			
						Canopy	Understorey	Turf	Encrusting
1	-1.25	1.8	95	1.0	5.2	1.1	31.5	39.4	65.9
2	1.25	5.1	177	1.0	5.7	7.4	12.5	23.5	88.9
3	3.75	3.9	228	1.1	5.5	4.7	6.8	7.5	83.9
4	6.25	2.7	196	1.2	5.7	1.3	2.9	3.2	77.2
5	8.75	2.7	186	1.2	6.5	0.0	2.5	1.3	82.1
6	11.25	1.4	94	1.3	5.9	0.0	0.7	1.3	75.2
7	13.75	2.0	2	1.0	6.0	0.0	0.0	0.0	50.0

Table 3. Number of red sea urchins measured and percent of urchins ≤50mm TD and ≥90mm TD for Pacific Fishery Management (PFM) sub-area 12-13, surveyed in the 2000 population survey in the Deserters Group area. SE = standard error of mean test diameter. R_T = percent of urchins of all sizes that were ≤50mm TD. R_S = percent of sublegal urchins that were ≤50mm TD.

Transects Used	Test Diameter (mm)				Numbers Measured			Percent of Total Urchins Measured ≤50mm TD		
	Mean	SE	Minimum	Maximum	Total	≤50mm TD	≥90mm TD	R_T	R_S	≥90mm TD
Within Beds	101.6	1.32	16	160	378	18	276	4.8	17.6	73.0
Outside Beds	102.5	0.57	6	165	1860	63	1358	3.4	12.5	73.0
All	102.4	0.52	6	165	2238	81	1634	3.6	13.4	73.0

Table 4. Estimates of density and biomass of red sea urchins (RSU), in Pacific Fishery Management sub-area 12-13, for the 2000 survey in the Deserters Group area of Queen Charlotte Strait. Estimates are for transects within red sea urchin beds recorded between 1997-2000, for transects outside the beds, and for all transects combined.

Transects Used	Number of Transects	Sum of Transect Lengths (m)	Mean Density RSU/m^2		Standard Error of Mean Density		Mean Biomass of RSU g/m^2		Standard Error of Mean Biomass	
			All Sizes	≥90mm	All Sizes	≥90mm	All Sizes	≥90mm	All Sizes	≥90mm
Within Beds	9	381	2.12	1.52	0.48	0.35	812.4	726.4	202.2	189.2
Outside Beds	48	1518	3.45	2.48	0.29	0.20	1318.5	1175.2	97.2	88.1
All	57	1899	3.18	2.29	0.27	0.19	1216.9	1085.2	95.0	86.1

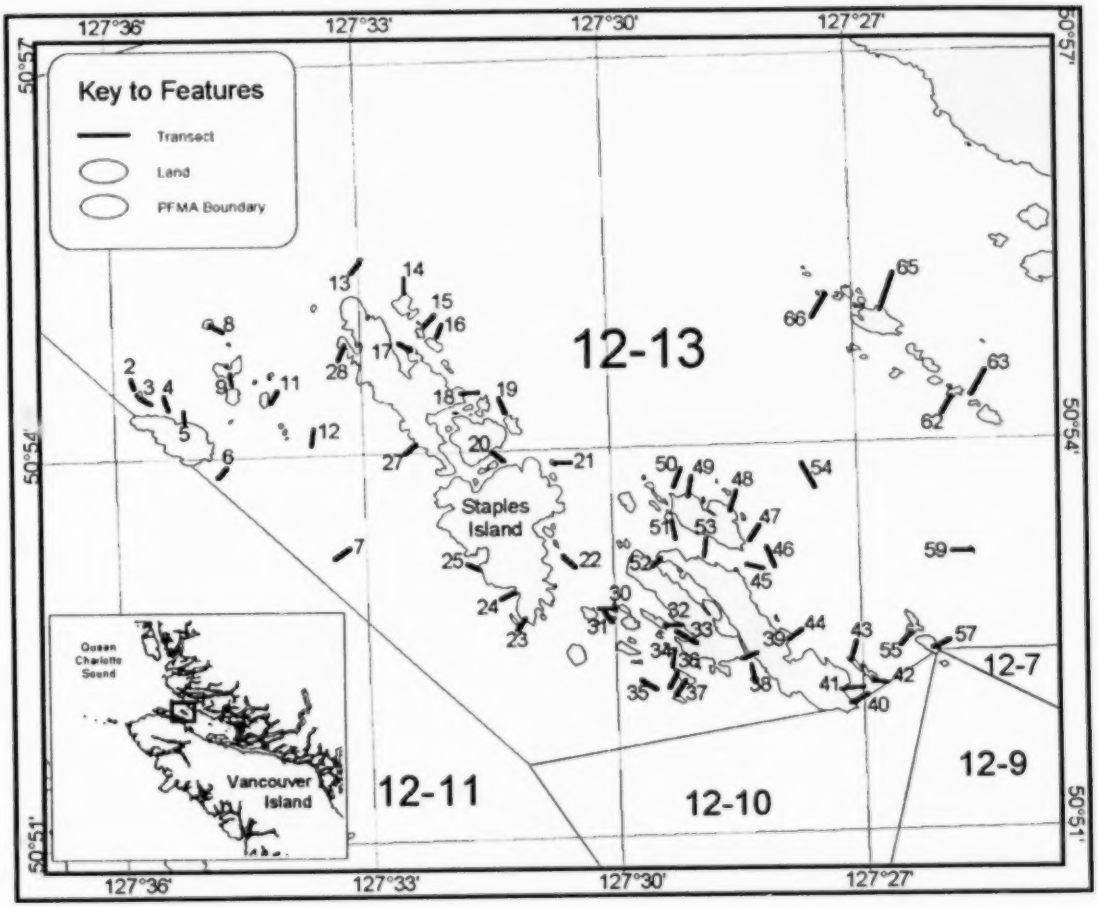

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted in the Deserters Group area of Queen Charlotte Strait, 2000. Hyphenated numbers indicate Pacific Fishery Management sub-areas and other numbers identify transects. Inset map indicates location of survey area.

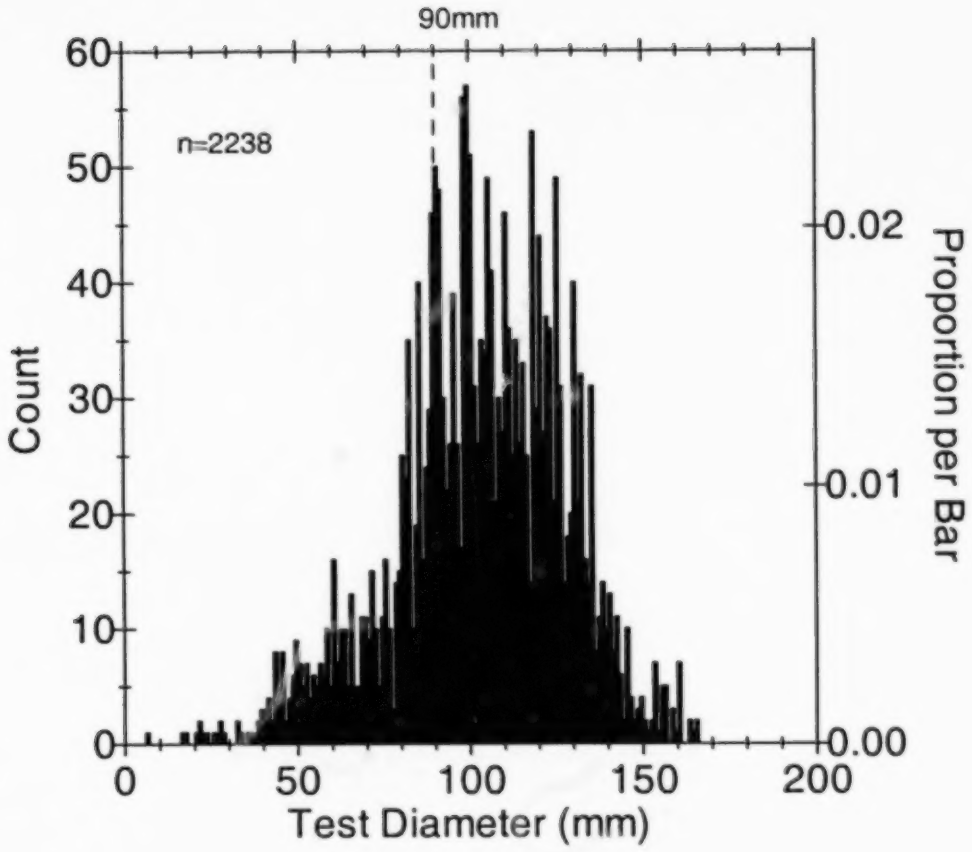

Figure 2. Size frequency distribution of red sea urchins measured on all transects during the 2000 survey in the Deserters Group area of Queen Charlotte Strait (n=2238). All transects fell within PFM sub-area 12-13. The dashed vertical line represents the 90mm legal commercial size limit.